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CLINICAL REVIEW

A meta-analysis and model of the relationship between sleep and depression in adolescents: Recommendations for future research and clinical practice

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SUMMARY

The purpose of this review was to quantify the strength of evidence for a directional relationship between sleep disturbance and depression in adolescents.

A literature search was conducted to identify research investigating the relationship between sleep disturbance and depression in adolescent samples (12–20 y). Twenty-three studies were identified; 13 explored associations between depression and sleep disturbance; seven examined the prospective role of sleep disturbance in the development of depression; and three investigated the role of adolescent depression in the development of subsequent sleep disturbance. Average weighted mean differences in sleep/depression-related outcome variables were calculated between adolescents with depression, and non-clinical adolescents, or those in remission.

Adolescents with depression experienced significantly more wakefulness in bed (sleep onset latency, wake after sleep onset, number of awakenings and sleep efficiency), lighter sleep (more stage 1), and reported more subjective sleep disturbance. Overall effect sizes from longitudinal and treatment studies suggest sleep disturbance acts as a precursor to the development of depression. At follow-up, depressed adolescents had significantly longer sleep onset, more wake after sleep onset, and lower sleep efficiency compared to adolescents who were non-clinical, or had undergone remission. Little support was found for a predictive role of depressive symptoms in the development of sleep disturbance. Based on these findings we propose a model to understand the development of depression from initial sleep disturbance, provide recommendations for clinicians and recommendations for future research.

Introduction

It is estimated that 20% of adolescents will experience a depressive episode by the age of 18 y [1], with the large majority (80%) experiencing a second episode within 5 y [2]. Similarly, up to 25% of adolescents report symptoms of sleep disturbance [3]. This rate increases substantially among adolescents suffering depression, with up to 73% also experiencing a comorbid sleep problem [4]. Both depression and sleep difficulties are associated with severe adverse effects including suicidal ideation, attempts and completions [5], school absenteeism and dropout [6], declines in academic performance [7] and cognitive functioning [8], and difficulties maintaining social relationships [9]. These adverse effects have profound consequences given the significant physiological and psychological changes occurring throughout this major developmental period [10]. Although the high comorbidity between depression and sleep disturbance is widely acknowledged [11], research is yet to evaluate the strength of the directional relationships in adolescent samples. Insight into these directions would facilitate our understanding of the development of either problem, and guide development of prevention and early intervention strategies to reduce their occurrence in young adulthood.

Literature exploring the relationship between depression and sleep disturbance in adolescents is heavily focused on the use of cross-sectional designs to compare the sleep of adolescents with depression to those without. These studies provide substantial support for an association between depression and sleep disturbance, particularly when sleep disturbance is assessed using self-report. Adolescents with depression consistently report significantly worse sleep [11,13], relative to adolescents with no symptoms of depression. Despite these subjective impressions, objectively (from polysomnography) these reports remain largely

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unsupported. A limited number of studies have supported the notion of less stage 1 and 2 sleep [14], more awakenings [15], and a shorter latency to rapid eye movement (REM) sleep [14–16]. The majority of studies, however, indicate no significant differences [15–18]. Given these studies are cross-sectional, any conclusions which may be drawn about the developmental interplay between sleep disturbance and depression are limited.

It is well established that sleep difficulties, such as insomnia, are predictive of depression in adults [19,20]; however it remains unclear whether a similar directional relationship exists during adolescence. Existing research using adolescent populations (the current review identified eight studies) provides mixed support for the notion that sleep disturbance precedes depression. Emslie and colleagues found adolescents who experienced a recurrence of their depression at follow-up (35.3%) had increased sleep onset latency and decreased sleep efficiency 12 mo earlier [21]. A series of studies conducted by Rao and colleagues also found increased minutes of REM sleep, decreased latency to REM, and a higher REM density was predictive of a diagnosis of depression in a group of adolescents at 7-y follow-up [22,23]. Using a quasi-experimental design, Rao et al. assessed the electroencephalographic (EEG) sleep of adolescents during an episode of depression as well as while in remission [24]. This pilot study ($N = 5$) revealed stable EEG sleep between episode and remission. Despite a decline in time spent awake across the night, no other significant changes were observed in sleep architecture or continuity. These results were replicated in a later study using the same methodology, with a larger sample ($N = 16$) [25].

Literature exploring the predictive value of depression for the development of sleep disturbance during adolescence is very limited. In a population-based study, Patten and colleagues examined factors associated with the development and persistence of sleep problems in 7960 adolescents [26]. Depressive symptoms significantly predicted the development and persistence of sleep problems at a 4-y follow-up. Adolescents who reported notable depressive symptoms were 50% more likely to develop sleep problems than those who did not report symptoms. In contrast, Simeon and colleagues included sleep disturbance as an outcome measure in their double-blind, placebo-controlled study for the treatment of adolescent depression with fluoxetine [27]. Although two-thirds of the adolescents treated with fluoxetine showed a marked clinical improvement on the majority of outcome measures (e.g., symptoms of depression and anxiety), sleep disturbance remained unchanged immediately following treatment and at a 24-mo follow-up.

The purpose of this review was to evaluate the strength of evidence for a directional relationship between sleep disturbance and depression in adolescents. A meta-analytic strategy was used to provide a quantitative summary of data from studies investigating the association between depression and sleep disturbance, those assessing the role of sleep disturbance in the development of depression, and those exploring the notion of depression as a precursor to sleep disturbance. Meta-analysis of similar and methodologically sound studies is considered to provide a high level of evidence [28], and potentially provides a more precise estimate of the underlying 'true effect' than any individual study alone [29].

Methods and materials

Literature search and inclusion criteria

Electronic databases, including MEDLINE, OvidSP, PsycInfo, PubMed, and online journals (e.g., Journal of Affective Disorders, Pediatrics, Sleep, etc.) were used to identify and retrieve research articles exploring the relationship between sleep and depression in adolescent samples. The search terms used included "adolescent sleep AND depression", and "adolescent depression AND sleep". Relevant articles were also manually identified from the reference lists of retrieved articles. Articles were included if they were peer-reviewed and described original research studies, including at least one measure of both sleep and depression. All literature were required to examine the relationship between sleep and depression in adolescents, therefore articles that used participants aged 12–20 y were included in this review. Studies that primarily focused on age groups outside this range were excluded. Articles were included only if authors provided descriptive statistics such that effect sizes could be calculated (i.e., means and standard deviations, proportions, confidence intervals, etc.). All articles were published in English. The literature search was conducted from April to September, 2013. Fig. 1 shows the flow of the literature search process.

Using the above criteria, 23 articles were identified. Of these, 13 explored the relationship between adolescent sleep and depression, seven examined the role of adolescent sleep disturbance in the development of depression, and three investigated the role of adolescent depression in the development of subsequent sleep disturbance (Table 1).

Data analysis

Data extraction

Sleep was primarily assessed using electroencephalographic (EEG) data. Outcome variables included sleep onset latency (SOL), wake after sleep onset (WASO), number of awakenings, time in bed (TIB), sleep efficiency (SE), amount of time spent in each sleep stage, as well as REM latency and REM density. Subjective reports of insomnia, hypersomnia, overall sleep quality and sleep disturbance were also included.

Depression severity was indexed using a range of widely accepted tools used to assess depression in adolescent samples and included, but were not limited to, the Hamilton depression rating scale [38], and the multidimensional child and adolescent depression scale [39].

Adolescents who met diagnostic criteria for major depressive disorder (MDD) [40] were included in the MDD group, while adolescents who did not were considered non-clinical adolescents. Adolescents in remission were those who no longer met diagnostic criteria for MDD for a minimum of 3 mo, and were medication free for at least 6 mo.

Effect sizes

For each outcome variable, a standardized mean difference effect size was calculated using the following formula, $d = M_1 - M_2/\mathrm{SD}_{\mathrm{pooled}}$. M_1 and M_2 represent group means while $\mathrm{SD}_{\mathrm{pooled}}$ refers to the pooled standard deviation across group type. For studies reporting only proportions, the following formula was used, $h = \emptyset_1 - \emptyset_2$, where $\emptyset_1$ and $\emptyset_2$ represent the arcsin transformation of the square root of proportions from each group, multiplied by two. In both cases, scores of .2 represent small effect sizes and scores of .5 represent moderate effect sizes. Scores of .8 or greater represent large effect sizes [41]. These effect sizes were then weighted by the inverse of their variance to calculate a weighted mean effect size (d_+). A weighted mean effect size was then calculated for each outcome variable [42]. A 95% confidence interval and a Z-score (the standard error of the mean effect size) were also calculated for each outcome variable.

Heterogeneity

The Q statistic was used as a test of the homogeneity of the effect sizes [43]. When significant, the Q statistic indicates that the observed variability in the study effect size is greater than expected

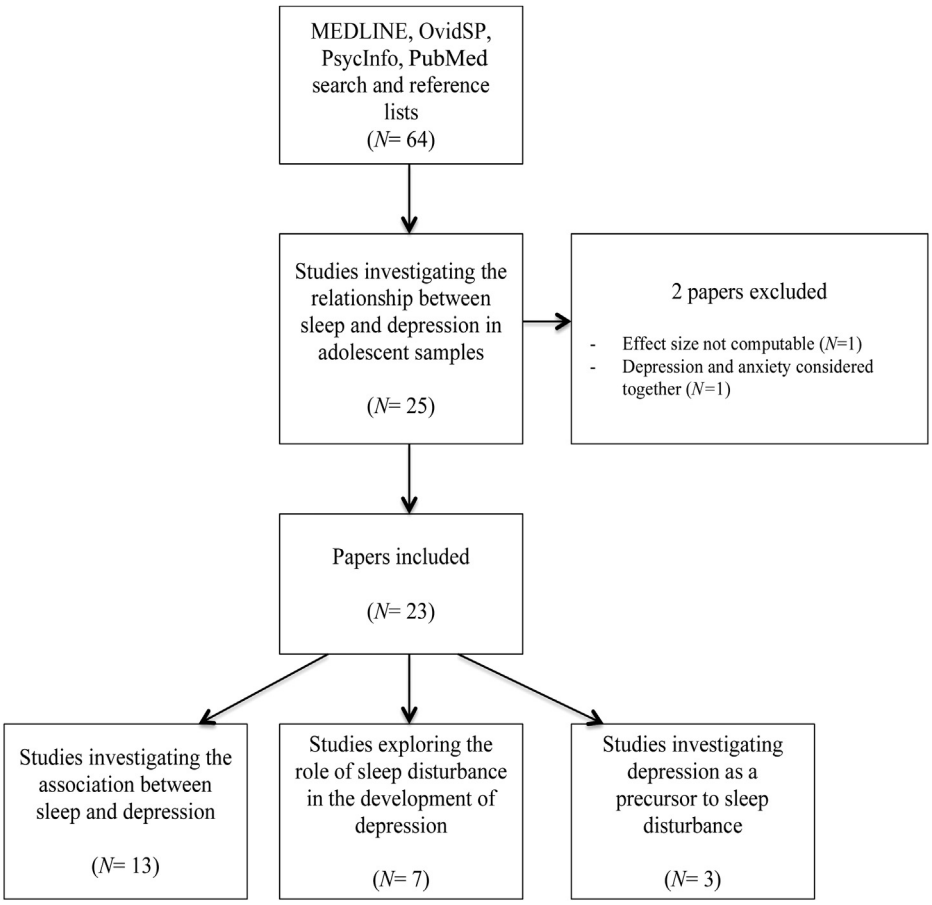

Fig. 1. The flow of the search for relevant articles.

by chance. The *Q* statistic is vulnerable to bias from sample size, therefore it is often used in combination with the I^2 statistic to quantify the degree of heterogeneity. In cases where the *Q* statistic was significant in the current analyses, I^2 is also reported.

Publication biases

The "fail safe number" was calculated to estimate the number of additional effect sizes (from non-significant, unpublished or missing studies) that would need to be added to the meta-analysis to reduce an overall effect size to a non-significant level [44]. If the "fail safe number" is larger than the number of observed studies, greater confidence can be held that the conclusions are robust to the 'file drawer problem' [93]. In addition to the "fail safe number", funnel plots were also constructed for each outcome variable to investigate the presence of publication bias. Funnel plots that appear symmetrical upon visual inspection suggest no bias is present.

Results

The association between sleep disturbance and depression

The overall weighted effect sizes for each sleep variable between the MDD and non-clinical groups are shown in Table 2 below. A total of 84 effect sizes contributed to these analyses. Adolescents with MDD reported significantly more subjective symptoms of sleep disruption, including sleep disturbance ($d_+ = 1.34$, 95% confidence interval (CI) = .53 to 2.19, $p < .05$), insomnia ($d_+ = 1.08$, 95%CI = .49 to 1.70, $p < .05$), hypersomnia ($d_+ = .48$, 95%CI = .26 to .69, $p < .05$), and sleep quality ($d_+ = -.39$, 95%CI = −.67 to −.11, $p < .05$), relative to the non-clinical group. These findings were supported with objective data, particularly concerning sleep disturbances involving wakefulness in bed. Depressed adolescents had significantly longer sleep onset latencies ($d_+ = .27$, 95%CI = .11 to .44, $p = .05$), more awakenings ($d_+ = .44$, 95%CI = .16 to .73, $p < .05$) and had lower sleep efficiency ($d_+ = -.38$, 95%CI = −.72 to −.04, $p < .05$) when compared to the non-clinical group. Adolescents with MDD also had a higher REM density when compared to non-clinical controls ($d_+ = 1.09$, 95%CI = .12 to 2.05, $p = .05$).

Heterogeneity in the significant effect sizes exists for symptoms of sleep disturbance, insomnia, and REM density. In each case, I^2 ranged between 87.6 and 91.4, suggesting at least 87.6% of the variance is generated from real differences between studies at the study level. Moderator analyses were conducted to explore potential moderator variables which may explain this heterogeneity.

Moderator analyses were conducted for the outcome variables of symptoms of sleep disturbance, insomnia and REM density. A random effects model was used for each outcome variable with age and sample size identified as potential moderating variables. In each case, age and sample size failed to explain any significant additional variance in effect sizes. This is unsurprising given the limited number of studies, and large amount of variance (88–91%) already explained from real differences between the studies, as indicated by I^2.

The predictive role of sleep disturbance in the development of depression

Table 3 shows the overall weighted effect sizes for each sleep variable between the MDD and non-clinical groups. A total of 62 individual effect sizes contributed to these analyses, 42 from

Table 1
Studies included in the meta-analysis.

Study	Sample size	Age (y)	Dx	Measurements		Quality ranking[b]	Association between sleep disturbance and depression	Sleep disturbance predicts depression		Depression predicts sleep disturbance
				Sleep	Depression			Longitudinal	Treatment	
Appelboom-Fondu et al. (1988) [15]	33	15.33 (2.77)	MDD mDD Non-clinical	PSG	CDI HRSD, WDSCA	22	•			
Bennett et al. (2005) [11]	383	15.80 (1.60)	MDD mDD Non-clinical	Sleep items of K-SADS, BDI	K-SADS BDI	23	•			
Dahl et al. (1990) [17]	67	15.23 (1.53)	MDD Non-clinical	PSG	K-SADS	20	•			
Goetz et al. (2001) [30]	77	14.83 (3.06)	MDD Non-clinical	PSG	K-SADS	23		•		
Goldstein et al. (2008) [5]	271	17.40 (1.81)	Suicide victims with a psychological autopsy, non-clinical	Sleep items of K-SADS	K-SADS	20	•			
Johnson et al. (2006) [31]	1014	14.36 (1.39)	Non-clinical	Self-report[c]	CDISC-IV	23	•			
Khan & Todd (1990) [18]	20	15.37 (.05)	MDD and non-clinical	PSG	BDI HRSD	18	•			
Lui (2004) [4]	1362	14.60 (3.40)	Non-clinical	Self-report[d]	YSR	23	•			
McCracken et al. (1997) [32]	33	15.80 (.44)	MDD Non-clinical	PSG	FH-RDC HDRS K-SADS	15			•	
Morehouse et al. (2002) [33]	81	13.64 (1.22)	Maternal history of MDD, no history	PSG	BDI HDRS K-SADS SCID	17	•			
Park et al. (2012) [12]	75,066	11–18[a]	Non-clinical	Self-report[d]	Self-report[e]	21	•			
Patten et al. (2000) [26]	7960	12–18[a]	Non-clinical	TAPS item[f]	TAPS item[g]	21				•
Patton et al. (2000) [13]	1947	14.50 (.50)	Non-clinical	CIS-R sleep items CIDI sleep items	CIDI CIS-R	18	•			
Riemann et al. (1995) [16]	20	16.30 (1.80)	MDD Schizophrenia Non-clinical	PSG	HRSD	13	•			
Rao et al. (1996) [23]	63	15.40 (1.30)		PSG	K-SADS	20		•		
Rao et al. (1997) [24]	5	16.20 (1.90)	MDD episode/ remission	PSG	HDRS K-SADS	10		•		
Rao et al. (2002) [22]	63	15.20 (2.18)	MDD Non-clinical	PSG	K-SADS	20		•		
Rao & Poland (2008) [25]	32	15.70 (1.67)	MDD episode/ remission	PSG	HDRS	14		•		
Roane & Taylor (2008) [14]	4494	15.83 (1.46)	Non-clinical	Self-report[h]	Self-report[i]	23				•
Roberts & Duong (2013) [34]	3134	11–17[a]	Non-clinical	Self-report[c]	DISC-IV	17				•
Shain et al. (1990) [35]	10	13–17[a]	MDD	PSG	HDRS SADS-L	13			•	
Vitiello et al. (2009) [36]	439	14.60 (1.5)	MDD/anxiety/ ADHD	ADS sleep times	SIQ-Jr	21	•			
Williamson et al. (1995) [37]	68	15.3 (1.7)	MDD episode/ remission	PSG	K-SADS	16	•			

ADHD = attention deficit hyperactivity disorder; ADS = adolescent depression scale; BDI = Beck depression inventory; CDI = children's depression inventory; CDISC-IV = computerized diagnostic schedule for children version four; CIDI = composite international diagnostic interview; CIS-R = revised clinical interview schedule; DISC-IV = the diagnostic interview schedule for children version four; FH-RDC = family history-research diagnostic criteria; HDRS = Hamilton depression rating scale; HRSD = Hamilton rating scale for depression; K-SADS = schedule for affective disorders and schizophrenia for school-age children; MDD = major depressive disorder; mDD = minor depressive/dysthymic disorder; PSG = polysomnography; SADS-L = schedule for affective disorders and schizophrenia-lifetime version; SCID = structured clinical interview for diagnosis; SIQ-Jr = suicide ideation questionnaire-Jr.; TAPS = teenage attitudes and practices survey; WDSCA = Weinberg depression scale for children and adolescents; YSR = youth self-report of child behavior checklist.

[a] These studies have only reported age range of their sample.

[b] Quality rankings are based on an amended version of the 'checklist for measuring study quality' (Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality of both randomized and non-randomised studies of health care interventions. J Epidemiol Community Health 1998; 52:377–384). This checklist was amended to omit irrelevant items 8, 23 and 24 which relate to adverse effects and randomization to intervention group. Possible scores range from 0 to 28, with higher scores indicating greater study quality.

[c] Items related to trouble falling asleep, waking in the middle of the night and finding it hard to go back to sleep, waking up frequently but able to go back to sleep, waking up very early, and non-restorative sleep, over the past 4 wk.

[d] Seven self-report items related to difficulty initiating sleep, difficulty maintaining sleep, and early morning awakenings.

[e] In the recent 12 mo have you experienced sadness or despair that interrupted your everyday life throughout two weeks' time?

[f] *"During the past 12 months, how often have you: felt too tired to do things?; felt unhappy, sad, or depressed?; felt hopeless about the future?; felt nervous or tense?; and worried too much about things"*.

[g] "During the past 12 mo, how often have you had trouble going to sleep or staying asleep?"

[h] "Please tell me how often you have had each of the following conditions in the past 12 mo… trouble fallings asleep or staying awake?"

[i] Adolescents were asked how often they felt depressed during the previous week.

Table 2
Association between sleep and MDD: overall weighted effect sizes for each sleep variable between MDD group versus control group.

Variable	k	d	Variance of d	95% Confidence interval	Z	Q	I^2
Objective							
SOL	9	.26	.02	−.001 to .51	1.95[a]	12.10	
WASO	3	.11	.02	−.12 to .42	−.70	.83	
NWAK	5	.44	.02	.16 to .73	3.02*	2.39	
TST	5	.07	.02	−.19 to .33	.54	3.27	
TIB	2	−.96	1.56	−.34 to 1.49	−.77	25.44*	96.1
SE	5	−.65	.02	−.95 to −.36	−4.37*	4.02	
Stage 1	6	.19	.02	−.09 to .47	1.34	4.60	
Stage 2	6	.08	.17	−.74 to .88	.18	36.61*	86.3
Stage 3	5	.32	.21	−.58 to 1.22	.70	33.52*	88.1
Stage 4	4	−.49	.23	−1.44 to .45	−1.02	18.40*	83.6
SWS	4	.13	.02	−.15 to .41	.90	2.75	
REM	7	.23	.02	−.04 to .49	1.66	7.01	
REM latency	8	−.24	.03	−.59 to .10	−.137	17.35*	59.6
REM density	7	1.09	.24	.12 to .21	2.20*	64.94*	90.9
Subjective							
Insomnia	3	1.08	.09	.49 to 1.70	3.58*	23.26*	91.4
Hypersomnia	2	.48	.01	.26 to .69	4.34*	1.15	
Sleep quality	1	−.39	.02	−.67 to −.11	−2.72*		
Sleep disturbance	2	1.34	.18	.53 to 2.19	3.21*	12.87*	87.6

Negative effect sizes indicate greater values for adolescents with MDD relative to control adolescents.
d = overall effect size, k = number of studies, Q = Q-statistic for the homogeneity of variances assumption, SE = sleep efficiency, SOL = sleep onset latency, SWS = slow wave sleep, TST = total sleep time, WASO = wake after sleep onset, Z = Z-value for two-tailed test of null.
*$p < .05$; [a] $p = .05$.
*$p < .05$

longitudinal studies and 20 from treatment studies. These analyses include both between-group effect sizes calculated between MDD and non-clinical groups (N studies = 4), and within-group effect sizes between MDD in episode and in remission (N studies = 4). Homogeneity was observed among effect sizes for each significant outcome variable.

Adolescents diagnosed with MDD had longer sleep onset latency ($d_+ = .43$, 95%CI = .09 to .76, $p < .05$), more wake after sleep onset ($d_+ = .58$, 95%CI = .28 to .88, $p < .05$), and lower sleep efficiency ($d_+ = -.51$, 95%CI = −.98 to −.03, $p < .05$) at follow-up (mean duration = 5.64 y, SD = 4.45), when compared to those who were non-clinical or had undergone remission since the initial assessment. These findings support those above (i.e., associations between sleep disturbance and depression), in that wakefulness in bed appears to differentiate those adolescents with MDD compared to those without or in remission.

Table 3
Sleep disturbance and the development of MDD: overall weighted effect sizes for each sleep variable between the MDD group and control group.

Variable	k	d	Variance of d	95% Confidence interval	Z	Q	I^2
SOL	7	.43	.03	.09 to .76	2.48	9.18	
WASO	5	.58	.02	.28 to .88	3.76	4.24	
TST	5	−.52	.18	−1.36 to .32	−.12	24.40*	83.6
SE	5	−.51	.06	−.98 to −.03	−2.09	8.46	
Stage 1	5	−.17	.05	−.61 to .27	−.74	7.30	
Stage 2	5	−.46	.10	−1.08 to .15	−1.48	13.56*	70.5
Stage 3	4	−.29	.16	−1.08 to .51	−.70	14.62*	79.5
Stage 4	4	−.23	.48	−1.58 to 1.13	−.33	38.75*	92.3
SWS	2	.33	.17	−.47 to 1.13	.82	2.59	
REM	6	.55	.13	−.16 to 1.26	1.52	28.11*	82.2
REM latency	7	−.78	.26	−1.78 to .23	−1.51	68.60*	91.3
REM density	7	.41	.08	−.15 to .98	1.43	24.61*	75.6

Negative effect sizes indicate greater values for adolescents with MDD relative to non-clinical adolescents, those in remission or successfully treated.
d = overall effect size, k = number of studies, Q = Q-statistic for the homogeneity of variances assumption, Z = Z-value for two-tailed test of null, SE = sleep efficiency, SOL = sleep onset latency, SWS= slow wave sleep; TST= total sleep time; WASO = wake after sleep onset.
*$p < .05$.
Note: McCracken et al., is an outlier for REM latency ($d = -6.81$; all other effect sizes range from −.33 to .63). Shain et al., is an outlier for REM ($d = 3.82$; all other effect sizes range from −.42 to .82).

The predictive role of depression in the development of sleep disturbance

The overall weighted effect sizes for each depression variable between adolescents with disrupted and good sleep are shown in Table 4 below. A total of only four effect sizes contributed to these analyses. Adolescents with disrupted sleep did not differ from adolescents with good sleep in terms of depressive symptoms.

Publication bias

The "fail safe number" for each significant meta-analysis is shown in Table 5 below. The "fail safe number" reflects the number of studies necessary to reduce these meta-analyses to a non-significant level ($p < .05$). In each case, the "fail safe number" for each analysis is larger than the observed number of studies. This indicates the current analyses are unlikely to be influenced by publication bias and therefore substantial confidence can be held in the conclusions of the current analyses. Funnel plots were also constructed for each outcome measure. In each case, the plot appeared symmetrical upon visual inspection indicating no bias.

Discussion

The present study summarized data from published studies assessing the relationship between depression and sleep disturbance in adolescents and used a meta-analytic strategy to evaluate the strength of evidence for a directional relationship between these variables. These results provide support for an association between depression and sleep disturbance in adolescents. Specifically, adolescents diagnosed with depression report significantly more sleep disturbance when compared to non-clinical adolescents, including reduced sleep quality and symptoms of both insomnia and hypersomnia. Objective assessment of sleep indicates adolescents with depression experience more wakefulness in bed (increased sleep onset latency and decreased sleep efficiency). These meta-analytic findings authenticate literature reviews of sleep disturbance and depression experienced by adolescents [44–47].

A model of the relationship between sleep disturbance and depression

Examination of overall effect sizes from longitudinal and treatment studies supports the notion that sleep disturbance acts as a

Table 4
Overall weighted effect sizes for each depression variable between the sleep-disrupted group versus control group.

Variable	k	d	Variance of d	95% Confidence interval	Z	Q	I^2
Depressive symptoms	3	−.06	.07	−.58 to .46	−.21	79.22*	98.1
Major depression	1	.28	.39	.14 to .42			
Suicide attempts	1	.85	.01	.69 to 1.01			

d = overall effect size, k = number of studies, Q = Q-statistic for the homogeneity of variances assumption, Z = Z-value for two-tailed test of null.
*$p < .05$

Table 5
Fail safe number for each significant meta-analysis.

Variable	*k*	FSN
Association between sleep and depression		
SOL	9	10.97
SE	5	30.50
WASO	5	13.88
REM density	7	60.45
Insomnia	3	119.93
Hypersomnia	2	3.03
Sleep quality	1	1.76
Sleep disturbance	2	86.06
Sleep disturbance → Depression		
SOL	7	17.13
WASO	5	24.31
SE	5	12.32

FSN = fail safe number, *k* = number of studies, SE = sleep efficiency, SOL = sleep onset latency, WASO = wake after sleep onset.

precursor to the development of depression. At follow-up (mean duration = 5.64 y), depressed adolescents had significantly longer sleep onset latencies, more wake after sleep onset, and lower sleep efficiency, when compared to adolescents who were non-clinical or had undergone remission since their baseline assessment. There was no support for a predictive role of depression in the development of sleep disturbance [25].

Research has identified the onset of puberty as a marker for the development of both depressive symptoms and sleep problems, however the underlying mechanisms driving this relationship remain unclear. Pubertal onset is associated with a delay in the timing of the circadian system (e.g., delayed sleep period) [11,47,48]. This delay in sleep timing would likely delay the latency to sleep onset, creating an opportunity to be awake in bed. Across the analyses performed in this paper, wakefulness in bed (sleep onset latency, wake after sleep onset and sleep efficiency) is the most consistent indicator of current and future depression in adolescents. Furthermore, wakefulness in bed is implied in some of the qualitative markers of sleep disturbance when self-reports are used (i.e., sleep disturbance, insomnia, sleep quality) [7,40]. And may reflect those who are depressed are more inclined to have negative responses in their self-reports [93]. Thus, adolescents with MDD spend more time lying awake in quiet darkness. An environment free of visual (i.e., darkness) and auditory (i.e., quiet) stimuli may be conducive to the intrusion of automatic thoughts. It is well established that dysfunctional cognitions and automatic thoughts about sleep, and the consequences of sleeplessness, are common in those experiencing difficulties initiating sleep [49–53]. These thoughts are typically highly repetitive, intrusive and ruminative in nature, akin to those characteristic of depression. We propose that increased wakefulness in bed may serve to reinforce ruminative thinking styles and hence perpetuate further sleep disturbance [49,51]. Our data indicate that over time, it is likely these processes could develop into depression. The Diagnostic and Statistical Manual of mental disorders (DSM) range of depression symptoms include those which clearly overlap with sleep disturbance, including irritable mood, fatigue and loss of energy, reduced appetite (specifically in the morning), and diminished ability to think or concentrate (during the day) [40]. Given the mean duration between assessments in the studies analyzed in this paper was 5.64 y, this is ample time to develop such depression symptoms as a direct result of sleep disturbance. Other depression symptoms may develop indirectly. For example, fatigue may reduce adolescents' partaking in usual activities and subsequently lose interest in these [40]. However, for other symptoms we have no current explanation (e.g., worthlessness, guilt, psychomotor agitation), despite that some symptoms have a clear unique association with both sleep and depression (e.g., suicide) [5]. It is also important to acknowledge the high genetic correlations observed between sleep disturbance and depression across a range of twin studies [54–57]. Results from these studies overwhelmingly suggest similar genes are likely to influence these phenotypes. Based on our findings and suggestions for possible mechanisms, we present a model for conceptualizing the relationship between sleep disturbance and depression here (Fig. 2).

Recommendations for clinical practice

The current findings support the importance of establishing and maintaining good sleep during adolescence. The prompt and effective treatment of sleep disturbances will ensure adverse effects of poor sleep, such as reduced academic performance [7,86], school absenteeism [6], and trouble maintaining social relationships [9] are ameliorated, and the likelihood of developing subsequent depression or mood dysfunction is minimized. Based on the present study, a cognitive-behavioral approach would be recommended. Treatment for adolescents should entail cognitive restructuring to target cognitions and ruminative thinking in the pre-sleep period and for waking bouts during the night, as well as behavioral techniques to reduce time spent awake in bed (i.e., sleep restriction, stimulus control therapy) [49,88–90].

Limitations and future research directions

The limitations of the current analyses should be acknowledged when interpreting these findings. Firstly, the current review identified only three studies that examined the predictive value of

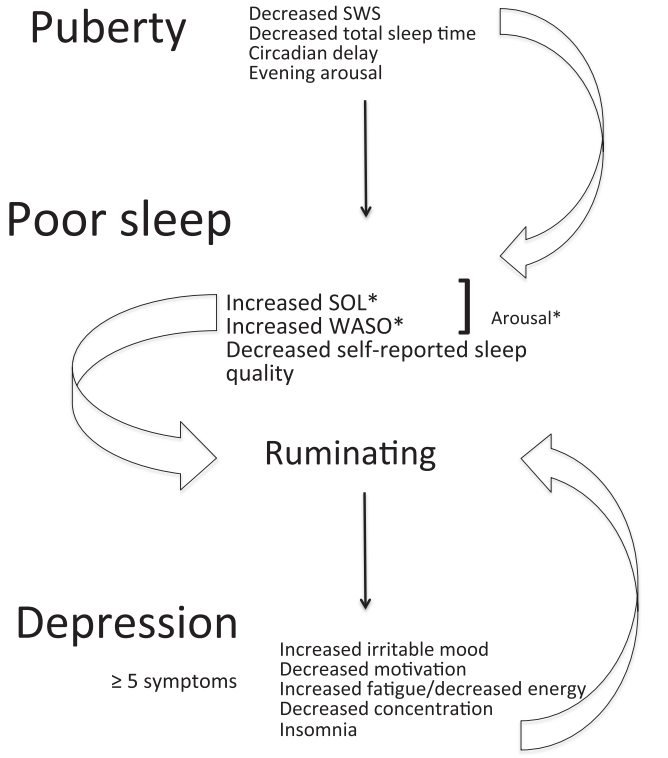

Fig. 2. Conceptual model for the relationship between depression and poor sleep. Note: * indicates wakefulness in bed includes self-reports of wakefulness in bed [6,8,57–85] SOL = sleep onset latency, SWS = slow wave sleep, WASO = wake after sleep onset.

depression in development of sleep disturbance. Until more research is designed to assess this directional relationship, firm conclusions about this direction of effect cannot be drawn. A comprehensive analysis of the bidirectional relationship between sleep disturbance and depression using the same sample would provide a sound basis to confirm the findings of the current meta-analysis. Secondly, many of the reviewed studies differed with respect to their definition of 'poor sleep'. Although this does not present a limitation for the objective variables derived from polysomnography, the relationship between subjectively defined sleep disturbance (e.g., symptoms of insomnia) and depression should be interpreted with caution. Ideally subjective symptoms should be measured using validated and standardized assessment tools, however the use of such measures will depend on the type of research design used (e.g., experimental or prospective/longitudinal). Several potentially confounding variables, such as gender [91], severity of sleep disturbance/depression and other comorbid psychiatric disorders (e.g., anxiety), were not controlled for in some of the studies included in the current analyses. We recommend future research should evaluate the predictive role of sleep disturbance in depression independently from other related variables. It is also important to recognize the role protective factors, such as physical activity and the parent–child relationship [92], may play in minimizing sleep disturbances and depressive symptoms among adolescents. Identification and promotion of these protective factors during pre-adolescence is a necessary avenue for future research.

Conclusion

The association between depression and sleep disturbance in adolescents was supported in the current quantitative summary of the literature. Adolescents with depression not only reported disturbed sleep but also objectively showed significantly more wakefulness in bed when compared to non-clinical adolescents. Examination of longitudinal and treatment studies suggests sleep disturbance is likely to predict depression rather than the converse. Based on this conclusion, we provide a model for understanding the development of depression from initial sleep disturbance. This model will require testing, not only from longitudinal assessments of sleep disturbance and depression, but also from prevention and treatment studies. It is our hope that the findings in the present study support the notion that the sleep of adolescents should be protected with the use of cognitive-behavioral methods, which so far appear to take approximately six sessions [49,87–90] as opposed to 12 sessions for the treatment of adolescent depression [90]. Thus, significant economic and social costs may be saved with a sleep-focused approach.

Practice points

1) There is a significant association between depression and sleep disturbance in adolescents. Adolescents with depression report disturbed sleep which is objectively confirmed by significantly more wakefulness in bed and lighter sleep relative to non-clinical adolescents.
2) Longitudinal and treatment studies suggest sleep disturbance is likely to predict depression.
3) Based on the current findings, we suggest that maintaining good sleep in adolescents using treatments with behavioral and cognitive components is likely to minimize the onset of depression.

Research agenda

1) More studies are required to examine the predictive value of depression in the development of sleep disturbance within adolescents. Ideally, the field needs more independent studies assessing both directional relationships in their samples.
2) Experimental and prospective studies are needed to confirm the proposed model between sleep and depression in adolescents.
3) Prevention and treatment studies are needed to confirm that minimizing wakefulness in bed may be a resilient factor protecting adolescents from depression.

Conflicts of interest

Both authors report no competing interests.

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